Use of Digital Learning Environments: A Study about Fragmented Information Awareness.

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Abstract. The study focuses on fragmented information awareness as a result of the cross-use of Digital Learning Environments (DLEs), rather than focusing on the use of individual Learning Management Systems (LMSs). This study goes beyond adopting an educational perspective as the classical studies on LMSs do. DLEs are defined as a plethora of digital systems that may be used within a teaching/learning context, including LMSs, but also social media shared dashboards communication tools, etc. used in such context. The paper addresses the issues encountered by different actors (students, teaching staff) when using DLEs. The study is theoretically anchored within the Human-Computer Interaction (HCI)/Computer-Supported Cooperative Work (CSCW) concept of awareness, repurposing the concept in an educational setting. The paper introduces fragmented information awareness, which is a new concept in the extensive existent body of literature on systems supporting Situation Awareness (SA), distributed, and shared awareness. The contribution of this paper lies in defining, describing, and addressing fragmented information awareness, grounded in empirical qualitative data. Moreover, the study addresses Universal Design (UD) issues by proposing a set of recommendations for non-fragmented information awareness from within and from without. Overall, the study subscribes to the third and fourth HCI waves.

Keywords: Digital Learning Environments (DLE), Learning Management Systems (LMS), Higher Education (HE), Human-Computer Interaction (HCI), Computer-Supported Cooperative Work (CSCW), fragmented information awareness, information awareness, Universal Design (UD).

1 Introduction

With the fast advancements in digital tools and learning environments, many Higher Education (HE) institutions have moved their teaching and learning towards digital platforms. However, without a framework to regulate which of these digital tools and learning environments may be used in HE, some challenges arise.

The focus of this study is on the use of Digital Learning Environments (DLE) in HE, rather than Learning Management Systems (LMS). We define DLEs as “digital

platforms, websites or specific webpages used by course instructors and students in a course for exchanging information or knowledge, relevant for their learning, respectively teaching, within the frame of the course." [1] (p. 272). DLEs comprise LMSs but are not limited to digital platforms that are built with the sole purpose of being used in a teaching/learning context. The notion of DLEs encompasses the plethora of digital platforms used in a teaching/learning context, including LMSs, email systems, social media platforms used for creating groups or teams, online-shared dashboards, or communication channels that support projects and cooperative work amongst students and teachers [1]. Each of these digital platforms is considered individually as a DLE when it is used for teaching/learning. However, a DLE is not limited to a single LMS; it is an umbrella term for all the digital platforms and tools used in a teaching/learning context.

Many studies have already been conducted investigating Learning Management Systems (LMS) over a number of years (see, for example, [2]–[5]). Such studies cover, in general, an educational perspective on systems created and dedicated *to* learning/teaching contexts. A few such examples of LMSs are Moodle, BlackBoard, itslearning, iLearn, etc. However, studies on LMSs disregard the fact that course instructors and students may use other digital environments or tools in their teaching/learning, e.g., DLEs.

Further, while LMSs are usually designed to support the management of information and mean that the user has some sort of *information awareness*, they are often analyzed from an educational perspective and less from an organizational perspective. This study goes beyond this educational perspective and assesses DLEs in the light of Computer-Supported Cooperative Work. This is both interesting and relevant because it shows how HE is more than a group of organizations "producing" or upskilling the workforce. It represents a complex public organization, similar to the National Tax Office, Public Hospitals, or The National Employment Agency, in terms of its routines, procedures, and laws, and also the digital systems it uses [1]. Moreover, analyzing HE from a CSCW perspective instead of an educational one sheds light on the use of a DLE plethora that may contribute to *fragmented information awareness* (compared to the information awareness that LMSs aim to provide). Moreover, certain situations may not be specific only to our data set as it relates to HE institutions, but also other similar institutions, both public and private, within or outside Norway. This particular perspective has not often been considered in the literature, offering another reason for the relevance of this study.

Specifically, the paper identifies a list of concerns that contribute to a fragmented awareness among students and Course Instructors (CI) in HE. The research question that we address is: *what are some of the challenges encountered by students and teachers to maintain a common awareness when using DLE in Higher Education?* Although the main focus of the study is on fragmented information awareness, the study also goes beyond the research question to locate the findings within the bigger framework of the fourth Human-Computer Interaction (HCI) wave [6], addressing issues such as the importance of universally designed DLEs.

The paper continues in Section 2 with a background to this study, positioning the study within the fourth HCI wave. Section 3 gives a detailed description of the concept of awareness. Section 4 details the data collection and analysis methods, and Section 5 presents the findings. Section 6 discusses the findings in the light of

fragmented information awareness, suggesting some recommendations for the use of multiple DLEs in HE. These recommendations are both organizational and designerly, meant to contribute to awareness from within and from without. Section 7 concludes the paper.

2 Background

This study is part of the UDFeed project [7]. Specifically, the project aimed to understand users' everyday interaction and use of digital systems used in Higher Education while gaining in-depth knowledge of how they experience those as Universally Designed (UD). This approach goes beyond the desktop metaphor, hypothesis testing, laboratory experiments, or user-centered design, emphasizing values and elements specific to the fourth wave, such as accessibility, policies and laws, and activism, in the form of Sustainable Development Goal 4 (SDG4) and UD, on accessible education. SDG4 has, amongst its targets, accessible and inclusive education at all levels and good quality of education [8].

In Norwegian HE, a recent regulation has been introduced regarding the universal design of Information and Communication Technologies (ICTs) of DLEs used in HE [9], [7], [8]. UD, derived from the field of architecture, has been associated with disability studies [12], [13]. From an international perspective, UD is defined by United Nations as: "the design of products, environments, programs, and services to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. 'Universal design' shall not exclude assistive devices for particular groups of persons with disabilities where this is needed." [14]. Moreover, UD is often associated with people with function variabilities. For instance, a recent Norwegian quantitative study demonstrated that many students in Norwegian Higher Education face barriers to learning: physical, pedagogical, digital, or other social barriers [15]. However, the study had a focus on barriers for people with disabilities [15]. Similar studies on universal design of ICTs for individuals with dyslexia (a learning disorder, that involves difficulty reading, due to problems identifying speech sounds, and learning how they relate to letters and words (decoding) [16]), and with other disorders have been undertaken [23], [24]. However, an accessible instructional environment is achieved through inclusion rather than individual adjustments [19]. One study supporting this idea was undertaken on the acquisition and use of universally designed digital exam environments [20]. The study suggested an iterative process model, ensuring that UD requirements are fulfilled and in line with quality assurance [20].

However, as previously mentioned, UD stands for *designing for as many people as possible*. However, as we can observe, all these studies reported, amongst their findings, problems, and issues that students with various disabilities or disorders encounter in Higher Education. Moreover, much of the focus to date has been on people with disabilities or cognitive disorders. We argue that users with or without any known physical or cognitive disabilities, face certain challenges in their interaction with these DLEs used in HE, regardless of their particular abilities [21]. This idea is supported by Martha Nussbaum (2004, p. 341) in [12] (p. 207), who

states that "we all have mortal decaying bodies and are all needy and disabled in varying ways and to varying degrees."

Studies on LMSs can be framed within the first, second, or third wave of HCI, or floating between different HCI waves (for HCI waves, see [22]). During the first wave, a lot of focus was placed on human factors and ergonomics, and experimental HCI (see [23]). During the second wave, the focus was on cognitive models and experimental HCI [24], i.e., for instance, how an LMS works for a number of students or course instructors, trying to improve the interface of specific LMS hypothesis testing, laboratory experiments, and on user-centered design. During the third wave, the focus was on the user experience [22], exploring the relationship between the researcher and the researched [24].

However, as several researchers [25], [26], [6] have pointed out, we should move beyond the user-centered design, focusing on the complex relationships between humans and computers and between different stakeholders within society. We should ask philosophical questions that do not limit themselves to the questions asked during the third wave regarding situatedness, values, and embodiment [25] but pushing beyond the institutional limits, focusing on accessibility, diversity, policies, and laws [6]. Questions regarding ethics and the individual's and society's responsibilities, as well as activism, should constitute the focus [25]. This study contributes to an understanding of these complex relationships between humans and computers, systems, and the use of various interfaces, by going beyond the desktop metaphor, moving beyond the concept of the use of LMSs, and rather focusing on the complex use of DLEs. Moreover, the paper goes beyond the instrumental use of the HCI/CSCW concept of awareness, bringing matters such as UD to the forefront of the paper. This makes the study potentially interesting for the fourth wave of HCI.

3 Theory: On the Concept of *Awareness*

The concept of *Awareness* has a long history across various fields, from Ubiquitous Computing and Context-Aware Systems to Intelligent Systems to Human-Computer Interaction (HCI) to Collaborative and Virtual Work Environments, and Computer Supported Cooperative Work (CSCW). This section gives a detailed account of the concept.

3.1 Defining Awareness

Awareness has its etymological roots in *awaredom*, which is defined as "the state of being on one's guard" [27]. *Awareness* is translated into German as *Bewusstsein*. In Norwegian, it is *bevishet om*, whereas, in Swedish, it is *medvetenhet*. In German and Norwegian, the term can be described as *paying attention to*, whereas the Swedish translation has a sense of *with knowledge, with consciousness (med + vetenhet)*. Being *aware* can be explained as the state of paying attention to something, of being knowledgeable about something, and of perceiving, recognizing, and understanding

something. Creating awareness amongst people regarding a specific situation, topic, or context, refers to creating a shared understanding [28].

Awareness systems are defined as "systems intended to help people construct and maintain awareness of each other's' activities, context or status, even when the participants are not co-located" [28] (p. iv). We can, however, distinguish between *awareness of people* and *awareness between systems* or *environments* [28]. Awareness is also defined as "the knowledge about the attention of others" [29].

3.2 Framing Awareness in HCI and CSCW

According to [30], the concept of awareness in HCI and CSCW dates back to the mid-1980s. First, the concept of awareness in informal communication was discussed in a study investigating collaboration amongst researchers [31]. The study addressed the importance of collaborative technology supporting this type of communication [31]. It laid the foundations for flourishing awareness research in the decades which followed. An extensive overview of awareness research is given by [32]. Amongst the types of awareness distinguished are: individual vs. group awareness, local vs. distributed awareness, mutual awareness, awareness of information taking place in the background, shared awareness, general awareness, or workspace awareness [32].

In CSCW, *awareness* is defined as: "practices through which cooperating actors while engaged in their respective individual activities and dealing with their own local urgencies and troubles, manage to pick up what their colleagues are doing (or not doing) and to adjust their own individual activities accordingly" (based on Gutwin and Greenberg (2002) in [33], p. 290). Awareness in cooperative work addresses cooperation amongst individuals in meaningful ways, where the actors' distributed activities are integrated and aligned with each other [33]. Further, within CSCW, awareness is described imprecisely as "actors' taking heed of the context of their joint effort" [33] (p. 286). Awareness is an *attribute of action* and should stand for something that one has knowledge about, or is consciously aware of: it "is only meaningful if it refers to a person's awareness *of* something" [33] (p. 287). Awareness refers to "a person's being or becoming aware of something," being "an integrated part of the practice and must be investigated as such," sometimes "an aspect of human interaction" [33] (p. 288). It is not considered to be separate from someone.

Situation Awareness. Situation Awareness (SA) was initially based on user-centered design, and it originated in the military, where a high level of awareness was needed [34]. It was defined as "being aware of what is happening around you and understanding what that information means to you now and in the future" [34] (p. 13). SA supports decision making and action [34]. Besides the time-critical fields, SA is also studied in weather forecasting, sports, acting, and, additionally, education [34]. SA is also a construct related to cognitive engineering and psychological processes [35]. SA includes three levels: perception comprehension, and projection [34]. It consists of a visual level, such as alerts and attention guidance, and a computational level focusing on display integration and predictive displays [35]. This construct is not only a "folk model," lacking a scientific ground, but it has a point. It is "a

continuous diagnosis of the state of a dynamic world," specifically in time-critical situations [35] (p. 144). SA, as a theoretical construct, was found to be very valuable in the Air Traffic Control (ATC) systems [35], [36]. SA in ATC emerged from studying the mental workload available during the flight of the pilot, co-pilot, and flight engineer [35]. Once studies had been undertaken on mental workload and the actors' residual attention, and SA, the flight engineer position was removed [35].

Another model of SA was developed by [37]. According to the model, awareness can be spatial, can cover a mode, or can be talked about as awareness of others in collaboration [37]. The latter includes informal awareness, conversational awareness, structural awareness, and workspace awareness [37]. Awareness in the context of cooperative settings refers mainly to the awareness of one another's work, activities, and tasks, with the purpose of coordinating the work of a cooperative ensemble [28].

The concept was later discussed again in connection with the case of the London Underground [38]. The *awareness* concept was not explicitly addressed in [38]. However, it was presented implicitly through the idea of making one's (own) work visible through "self-talk," making *the other* (e.g., the passenger, the controller, Divisional Information Assistant) *aware* of the ongoing activities, tasks, or eventual errors.

Distributed and Shared Awareness. Studies on media spaces on the geographical distribution of teams have also observed that awareness is an essential element that has to be taken into consideration when designing systems for cross-site cooperative work [39]. Videos, protocols, and other documents were initially introduced, followed by real-time transmission of audio and video, to maintain awareness across different sites [39]. Systems supported occasional discussions, video phone conversations, group discussions, video recording, presentations, and project work [39]. Portholes was one such project at Rank Xerox EuroPARC in Cambridge (UK) and Xerox PARC in Palo Alto (California) [40]. The project was one of the first media space projects to focus on real-time remote collaboration supported by audio and video [40]. The project aimed to promote shared information and distributed awareness [40]. Other similar systems are Polyscope and Imager [40], Peepholes, VideoWall, Telemurals, Thunderwire, Audio Aura, Nomadic Radio, Team Portal, Electric Lounge, Slideshow, Awareness, PRAVTA, and WatchMe [41]. These were also implemented to support awareness for distributed work [40]. Similar projects on media spaces included: VideoWindow, Belicore, Ravenscroft Audio/Video Environment (RAVE), Computer Audio Video Enhanced Collaboration, and Telepresence (CAVECAT), TeleCollaboration, and Kasmer [39]. There are some other early examples where shared awareness was studied within collaborative writing systems, such as Quilt, PREP, GROVE, and ShrEdit [42].

Further, with the World Wide Web and evolution of mobile phones to smartphones, today, we can find a number of technologies that support or are designed for awareness, not only in the systems used at work, but also those designed for leisure, or used in the home. Instant Messaging (IM) programs such as Yahoo! Messenger or Microsoft MSN support various kinds of awareness, e.g., statuses as *Available, Away, Do Not Disturb*. Skype and other chat programs, as well as email platforms, also have built-in features supporting these types of awareness functionality. More modern systems of collaborative virtual environments, e.g.,

document sharing systems: Google Drive, Dropbox, Slack, Microsoft Teams, also embed awareness in different ways. They make visible which of the team members are online and which are offline, by showing in real-time who is editing a document, or by showing the history log of a document.

Further, the literature also talks about collective awareness, as a result of social and sensor networks [43]. Finally, hyper-awareness refers to the continuous social awareness shared amongst individuals, by staying in touch with each other, regardless of individuals' locations [44]. Hyper-awareness involves forms of micro-coordination, where people coordinate with each other everything related to time and place, at short time intervals [44]. This type of awareness is very similar to passive context-awareness systems, where the users distribute information about themselves passively, i.e., without the need to have direct access to mobile technology [44]. One such example is the use of scheduled Facebook posts. An example of a system supporting hyper-awareness is Swarm, a group-based messaging system [44]. Further, Vertegaal (1999) defines micro-level awareness as including the implicit collection of awareness information, i.e., requiring low mental load and fewer interruptions in activities [29]. This type of awareness is referred to as *peripheral awareness* [45].

Although the concept of *awareness* in its various forms has been much discussed in CSCW and HCI fields, *fragmented information awareness* is not common within the available HCI and CSCW literature. Based on this study, this issue is defined and discussed in Section 7 of the paper.

4 Method

We collected the data for this study through the Story-Dialogue Method (SDM) and interviews. The SDM was undertaken with students and Teaching Assistants (TAs), whereas the interviews were conducted with Course Instructors (Cis). Both participant groups were part of the same HE institution.

4.1 Story Dialogue Method

To access students' personal experiences and involve students equally at all stages of data collection, we chose the SDM as our method. SDM is a narrative method based on an in-depth structured dialogue [46]. In-depth reflections on the advantages of this method over other methods, such as digital storytelling [47] or co-construction of stories [48], are given in [49]. The theme of the SDM was: HE students' experiences with DLE used in HE. The data collection was structured into three stages: recruitment, SDM process, and closure. Below, we discuss the recruitment process, the participants, their roles during SDM, and the data collection and analysis method.

Recruitment. The student participants were recruited from a Norwegian university in Southern Norway. The invitation to take part in the study was issued through an open call for participation on repeated occasions by the authors (DS, JH). The recruitment of the participants was achieved through both purposeful and snowball sampling: the

participants were HE students. The participation required the preparation of a *personal story* – a self-interview related to the study's theme. The method also required time for the data collection to be allocated on a pre-set date.

The initial intention was to recruit two groups of bachelor students for the data collection through SDM. Over 300 students following ICT-oriented bachelor programs were invited to take part in the study, with no obligation to take part. Three bachelor students registered initially for the study but later showed no further interest. However, one master student present during the open-call expressed an interest in taking part in the SDM. Further, the authors (DS, JH) gave a presentation to 17 TA students. TAs were both bachelor- and master-level students. Two other master students registered to take part in the study. Finally, it seemed the study and method used was more attractive for students at master level, due to their interest in the method being applied in their master theses eventually, but also perhaps being more used to participating in research projects. Reflections on this method, its advantages, and disadvantages, were reported in [49].

Participants. Five master students from one study program responded positively to the call to take part in this study. All of them participated in all stages of the data collection and analysis process. Four of the participants were first-year master students, whereas one was a second-year master student. None of the participants reported any disabilities. Three of the participants were interested in universal design. Two had their background in pedagogics, whereas two were, at that time, working as TAs. However, only one of them chose to explicitly relate to the experience of being a TA during the study.

Roles. For each of the stories shared, the participants had one specific assigned role: story-teller, story-listener, or story recorder. Each of the stories was regarded as a *self-interview* in a particular situation. Each of the participants had at least two roles, during the study period: story-teller, story-listener, story recorder, and facilitator. The roles were shared, in a regular pattern, amongst participants. The authors (DS, ZP) facilitated the SDM, with the following roles: primary facilitator (DS), and observer (ZP). Besides their pre-assigned roles, the facilitator and observer, the authors (DS, ZP), also acted as participants, taking on the role of story recorder, jotting down notes or quotes while listening to the participants. Neither of the authors (DS, ZP) presented any stories.

Data Collection and Analysis. One hundred and ninety-seven (197) story cards were collected during SDM. Each of the story cards contained textual data ranging from one word to several sentences. The data collection was divided into five steps, as follows: a descriptive and reflective part comprising introduction and story-telling (Step 1); a reflection circle (Step 2) resulting in 57 story cards; an analytical part comprising a structured dialogue (Step 3) resulting in 132 story cards; reviewing the story records (Step 4); and a concluding part comprising: creating the insight cards which represented the theory notes, and the end of the study (Step 5), resulting in 8 insight/theory notes. Each of the study parts was documented through story cards. Color codes were used for each of the steps.

4.2 Interviews

Four interviews were undertaken with the teaching staff. The interviews lasted for about one hour each. These resulted in about 100 pages of text transcribed verbatim by the author (DS). The textual data were analyzed through systematic text condensation [50]. The analysis was done in four steps: (Step 1) getting an overview of the data (themes: n=8, prioritized themes n=3); (Step 2) identifying and categorizing meaning units (codes: n=245); (Step 3) condensing the codes into meanings (meaning units organized in subgroups: n= 73, categories n=27); (Step 4) finally, during the last step, synthesizing the condensed data into concepts.

4.3 Ethical Considerations

All the participants were given detailed information about the study, with a chance to ask questions prior to and during the study, and they could withdraw at any time without giving any explanation and without any consequences for them. The participation was based on free will. All the participants willing to participate in the study signed informed consent before taking part in the study. The study follows the ethical guidelines from the Norwegian Center for Research Data (NSD) ref. number: 55087/589513). This work was performed at the Services of Sensitive Data (TSD) facilities, owned by the University of Oslo, Norway, operated and developed by the IT service group at the University of Oslo, IT-Department (USIT) (project number: p400).

5 Findings

In this section, we present the findings from each of the data collection methods: SDM and interviews.

5.1 Story Dialogue Method – Findings

Fragmented Understanding of Course Instructors' Mediated Feedback through DLEs. In general, the students noticed that the course instructors' feedback mediated through DLEs was mostly textual. One student noted that although human feedback is important, short textual feedback is not helpful, classifying it as "careless." In general, the students seemed to dislike vague feedback or a lack of Course Instructors' (CIs') feedback. They pointed out that such mediated feedback through DLEs is not "rich enough" or "nuanced" enough for effective communication. They stressed that the information that needs to be communicated is often lost in this way. The students concluded that textual feedback from the CIs is hard to interpret.

Moreover, the participants felt that human-mediated feedback that was only textual (unimodal) was, at times, difficult to interpret. They argued that alternative solutions should be provided, such as multimodal feedback supported within DLEs,

through textual, audio, video, schematics, and diagrams. In this way, according to the participants, the synchronous or asynchronous communication supported by DLEs would be richer. However, one of the participants noted that multimodality could also be perceived as *clutter*.

DLEs' System Feedback and Languages. The students offered reflections on the challenges of designing DLE virtual interfaces in terms of supporting several languages. They focused especially on the fact that Norway has two official languages (the old language, Norwegian Bokmål, and the new language, Norwegian Nynorsk), and how this poses challenges for the design of DLEs. This is of relevance for UD, concerning students with an immigrant background that have learned only one of the official languages.

(Dis-)Empowerment of the User through DLEs' Design: Fragmented Control. In general, students claimed more empowerment on the user's side. The story cards revealed that one should focus on the adjustments of the existing DLEs rather than developing new ones. From the user perspective, the students mentioned that the systems are "*too loose*," and the issues that the users encounter are often fragmented. They noted that the user usually needs to act in case of a system failure and "*break the system walls*," meaning that there are often quick fixes carried out instead of the underlying design issues being addressed. The students mentioned that, in case of system failures, the involvement of the user is usually required to report the problem. But many users choose to stay silent, and no real changes take place. They also pointed out that when there is a system failure, an alternative solution should be pointed out by the system itself. The students also indicated that there is often an issue of power relations between systems and humans. The students also pointed out that the systems are designed in such a way that there is no opportunity to give negative feedback and that DLEs must invite human feedback.

DLEs' Design Generates Fragmented Emotions: "I am Personified with my Problem." The students perceived DLEs as a barrier, where the user had to accommodate the DLEs and not the opposite. They indicated that there is an imbalance between what the systems look like they do vs. what they actually do. This imbalance in expectations often triggered emotions in the user. For instance, the students pointed out feelings of frustration when the DLEs did not work correctly, and the situations occurred repeatedly. They also pointed out feelings of sadness or confusion when the DLEs' feedback was vague, and they did not understand how to navigate the system further. Some cards indicated that emotions are strongly connected to the system feedback one receives. One participant stated both verbally and on the story card that he planned to take extreme measures, such as installing a video-camera because a DLE system breakdown had occurred multiple times, which generated strong emotions of frustration for him.

The presented findings above are supported by the illustrated examples from different story cards in Table 1.

Table 1. Examples of illustrative story cards

#	**Examples of story cards**
Human mediated feedback through DLEs	"the existing system is only text-based"; "desire for a "richer" environment"; "want more/different kinds of media representations"; "Would combining different types of communication like voice/text in a single 'thread' of discourse create clutter?"; "Written feedback can be hard to interpret."
DLEs' system feedback and language	"It's a challenge for Norwegian speaking to understand Nynorsk vs. bokmål."; "The options in technology have to do with language – it is not understandable, clear."; "Nynorsk vs. bokmål"; "Language can be a problem, and it is necessary to deal with it. Bokmål vs. Nynorsk".
DLEs' design gives fragmented control to the user	"I wish to troubleshoot issues myself, less dependent on others"; "If you end up asking yourself <<how can it be so difficult?>>, there is something probably difficult to it"; "I can share my story with others. I know more people have the same problem. Even if the problem is small and fragmented, many of us have the same problem. This shouldn't be disregarded"; "Make other people complain because others have the same problem"; "Lower the barrier: design the system, so it doesn't break down. Design for people"; "If I have control over the system, I wouldn't be dependent on it"; "Even though you are right, constantly having to complain about minor issues might feel uncomfortable. → Might lead to minor issues not being reported"; "I am 'stuck' because it's someone else's responsibility & I am relying on that service"; "I don't have control"; "We do have power with our voices, and if we keep quiet, then nothing will happen. I think maybe we should contact actual people who are responsible for the system. Not just ignore this issue,"; "Being able to combine multimedia. That would be great"; "We make things work regardless but at some costs (time, resources)."
DLEs' design generates fragmented emotions	"I chose the story because many emotions are involved"; "many emotions involved because it [the system] did not work; it happened multiple times; I am personified with my problem."

Condensation of Learnings. Finally, in the last step of the SDM, the participants were asked to condense their learnings, in such a way that they could be generalized for others who had not taken part in the study. The learnings are represented in Table 2 below, as initially formulated by the participants.

Table 2. Theory notes created by the participants themselves at the end of SDM

#	Theory notes from the insight cards
1	Human and system feedback is a 2-dimensional entity, where one axis is represented by: • the richness of information (a property of feedback; • and the other by the age, potential, and the capacity of interpretation (properties of the receiver of the feedback).
2	Textual feedback is different for different people.
3	The systems are a good representation of the "people" behind the system.
4	It is important to know/understand who you are giving feedback to.
5	How the feedback is understood depends on the receiver.
6	Feedback or lack of feedback can cause emotion.
7	Invite collaboration on: • feedback; • equalizing power or perceived power; • communication.
8	Create open systems (open door metaphor) that are open for: • giving feedback and • fixing it yourself.

5.2 Findings from the Interviews

Use of Different DLEs. Eighteen DLEs were mentioned by the CI participants. We divided these into official and non-official. The official DLEs are required by law to be universally designed. However, we wish to point out that non-official DLEs are also in use. This means that some of the students may be affected indirectly, i.e., by not being able to use these DLEs due to these not being universally designed.

The official publishing system was used only by three of the CI participants. Only two participants were aware of the introduction of a new DLE, whereas only one was using it. The only communication channel that was used by all CIs in their communication with students was the official email system. Several of the participants used different external systems in their teaching. Moreover, only one was using the official examination platform. One of the participants developed their DLE for the assessment of students. The same participant found the use of different social media and other external tools in a teaching and learning context to be distracting. However, all the other participants were using some kind of external system (DLEs).

Although 18 systems were identified as having been used by different CIs, one of the interviewees still mentioned that there is a lack of supervision for DLEs. He mentioned that it is very hard to keep track of all the projects and students through the email system, without having a dedicated platform for this. The current DLE that they were using appeared not to support the supervision of students or be structured well enough to support this. However, while we saw that many DLEs were in use, we could also observe that many of them were used for specific purposes. In essence, they were dedicated systems for a particular aim: a publishing system, submission system, quiz tool, assessment system, examination system, communication systems,

etc. Table 3 gives an overview of the systems in use, as described by the CI participants.

Table 3. Overview of the digital learning environments and tools

#	Participant (CI) / Systems used in an HE Institution	#1	#2	#3	#4
1	Publishing system	X		X	X
2	Internal submission system	X	X	X	X
3	Internally and externally used submission and assessment system	X		X	
4	External communication system				X
5	External quiz and input system 1	X		X	X
6	External quiz and input system 2	X			X
7	Administrative system		X		
8	Own developed assessment system		X		
9	Email	X	X	X	X
10	New DLE system		X		
11	Third-party application		X		
12	External quiz application		X		
13	Social media platform 1		X		
14	Social media platform 2		X		
15	Web service for forum discussions and wikis		X	X	
16	MOOC platform				X
17	Examination platform				X
18	Screen and speech recorder software				X

Tensions in Expectations amongst Different Actors.
One DLE vs. Several DLEs. While some of the CI participants were hoping for one integrated system, some pointed out that it would not be the right solution to build one "*mammoth*" system: "*I wish that everything was in one system*." The interviewee continued:

> *P:* "*Absolutely, I do have a strong opinion on this. In the sense that, that I don't really like the idea of building a mammoth, doing it all, because it is not really possible for a software to do it all, like discussion, and courses, and projects, and everything. If you try to build a mammoth, then everybody would want a different thing.*"
> *F1: "By a mammoth, you mean?"*
> *P: "A big elephant. So, if you try to build something big that will try to do it all, then it's no success*."

Visualization of Information in DLEs. Based on the SDM, students seemed not to be very satisfied with the way DLEs provided supported feedback from CIs. We also

found that they were looking for *nuanced* and *rich* feedback that is personalized and explicitly aimed at them. They also mentioned that they wished for visual representations of feedback that is easy to understand. However, one of the CIs seemed not to agree. According to the participant, students *preferred* textual feedback, claiming that less than 5% understand visual feedback represented through diagrams. However, one of the CIs agreed with the students that the DLEs should support visuals, such as drawings. She found this relevant, especially for the DLE used in the examination.

While students were able to draw schemes and diagrams on the earlier paper exams, with the digitalization of examinations, it seems that students encounter challenges when they need to draw on computers. The CI participant found this challenge relevant for students from different fields, including medicine, where students need to draw a lot, for instance, in anatomy. She also stated that, currently, it takes a lot of time to complete the drawings with the existing software.

Fragmented Expectations of the Course Material Format in DLEs. One of the CI participants was complaining that he is almost forced to record his lectures. Although he considered it not to be very enjoyable to be listened to, he felt that he had to log them to avoid complaints from students. While this was experienced as stressful for one participant, one CI participant explained that the HE environment should be inclusive. She meant that people who cannot attend the lectures should still be able to access the course materials. The same participant expressed how she likes that the systems are open and accessible for everyone, instead of having closed systems that ask for credentials of the users, saying: "*everybody can see it, but not everybody can edit it*."

Fragmented Awareness in Universal Design. One of the participants pointed out that the DLEs need to be developed *for* the users, but also by not dismissing to obey the Educational Laws:

> *P: "So, this is kind of the problem: the developers and the end-users. The user can be stuck in their own ways and can be stubborn, but sometimes the developers do not make life easier for the users. What users like is easy tools to use, and easy to manage and easy to do things in it. […]. So yeah, the developers need to make the life of the users a little bit easier, because the users will always go to the easiest options. And for now, for instance, the easiest option is Google Docs or Dropbox, or stuff like that, because it is very, very easy to manage. But now it depends. Because the Educational Tools have to obey Educational Laws as well, right?"*

One of the laws that we mentioned in this paper is the application of UD in DLEs in HE. Concerning UD, the majority of the students were aware of it, but they often associated it with people with disabilities. On the other hand, only one CI had a deeper knowledge of UD, with regard to accessibility and usability testing. However, none of the CI were aware of the One of the CI associated UD with the idea of ethics and that it should be some support for students with disabilities at the institutional level. In contrast, one of the CIs said that their own developed system is only click-based. Moreover, he confirmed that the system did not use any colors, and therefore should comply with UD principles and standards. As he said:

P: "I mean, if you can use [system #10], you should use this. I mean [system #10] is approved, and this isn't doing anything, anything which [system #10] isn't using. Actually, we are using, we are doing less than it's expected from [system #10]. So if [system #10] is accepted, this should just fit in."
F: "Okay."
P: "Because you are not using any colors, in terms that you cannot see any colors, little text, and it's structured, you just click, drag-and-drop."
F: "Do you plan to change the interface for the app, or is it going to be the same?"
P: "No, it's going to be approximatively the same, because it's going to be very clinical, very straight. Because the magic happens underneath the interface. It's going to be very neat, very boring, just click. It should be as simple as possible."
F: "Aha. Okay. And what's your experience with [system #10] with regard to universal design?"
P: "It works for me."
F: "It works for you. Okay."
P: "Yeah. So I… yeah."
F: "Any bad experiences?"
P: "No, not from a universal design point of view. I just… It works for me. I am happy."

The general impression was that both CI and students had a shallow understanding of UD except for one CI who had somewhat more in-depth knowledge on a micro-level, in terms of technical expertise on UD.

Fragmented Awareness.
Fragmented Distribution of Course Materials in DLEs. One of the participants pointed out that using dedicated DLEs or tools is fine if multiple DLEs are not being used for the same aim. The same participant mentioned that it is very difficult for the students to find the course material spread over different DLEs. She also pointed out that there are no agreements or sets of rules amongst the CIs on how to publish and distribute course materials:

"*So I think that more dedicated tools are fine. But the main problem is that maybe that there is no common approach by lecturers in what they use. So, one holds their lecture material on [C], one holds it on [A], one holds it on their USB key, whatever. So, it's very difficult for students to understand where to find the material, if all the material is there, and when it is uploaded and so on and so on. I see the problem not in using 20 tools, but in using 20 different tools to do the same job. So, it would be nice if we were using much fewer tools when it comes to content and holding, to chats, to whatever, and to, of course, project deliveries. I think it would be much easier for the students to have these tools of choices*."

Moreover, it also seemed that the students had *to adapt* to the various choices that CIs were making concerning publishing, submission of assignments, and examination. At the same time, students missed out on the feedback received from the TA because of the use of different various DLEs. Further, while each of the 18 DLEs was useful in its own way, the participants were complaining about the structure of the system, in terms of what has to be learned for each of the DLEs.

Fragmented Awareness: Email as a Solution? One of the participants mentioned, however, that one of the issues with having multiple DLEs in use is that the user does not get notified about eventual updates in each of the systems, and it is hard to find the relevant course material. One of the CIs proposed that *email* could be the junction point where the user, whether student or CI, could receive notifications from various DLEs. The same participant mentioned that while almost every DLE has a built-in *Calendar* function meant to be used, the user will only stick with one of those: usually, the one connected to the *email* (Outlook or Gmail). Therefore, she concluded that having a *Calendar* function in each of these DLEs is not relevant, and such functions could perhaps be removed.

6 Discussion

Practice refers to what people actually do and what they experience when they are doing things [51]. Practice is the symbiosis of action accompanied by meaning [51]. When action and meaning are divorced, there is a lack of context, and thus, fragmented awareness follows.

In this study, we have studied the practice of using DLEs and digital tools by both students and CIs, and how the use of multiple DLEs may lead to *fragmented information awareness*. The research question that we addressed at the beginning of the paper was: *what are some of the challenges encountered by students and teachers in maintaining a common awareness when using DLE in Higher Education?* It seems that the rapid proliferation of systems and a lack of policies places certain demands on users: students, CIs, and the HE as an institution. A byproduct of our findings is the theme of fragmented information awareness. This is defined and described as part of an ecological system, and explained in terms of context and orderliness, as follows. At the end of the section, we come back to the UD matters presented in the background and suggest some recommendations for HE institutions where several DLEs are used.

6.1 Defining *Fragmented Information Awareness*

Awareness is always related to the *awareness of someone about something*. As we have seen in the previous sections, situation or context-aware systems have been used for a long time in the design of time-critical systems: in the automation of power plants, aircraft and air traffic control systems, or more recently in smart cars, industrial robots, or other autonomous devices. Giving control to the user relates to keeping the user situation-aware [34]. While others have defined awareness as knowing what is happening in the work environment surroundings [40] (p. 541), some have established awareness as "an *understanding of the activities of others*, which provides *a context for your own activity*" [42] (p. 107). The authors talk about awareness information for coordinating activities between several actors [42]. Based on this study, we argue that, due to a high increase in the digitalization of HE, a fragmented information awareness has been introduced by the use of multiple DLEs.

Fragmented information awareness is a byproduct of the study performed. Before we go further, we wish to define and describe fragmented information awareness.

A *fragment* is a detached, isolated, or incomplete part from a whole, a portion, or a fraction of something [52]. When we talk about fragmented information awareness, we refer to a type of awareness that is incomplete, that is missing parts that are de-fragmented. The fragments are here pieces of information that are missing. Awareness is not perception, but it embeds perception along with comprehension and projection [34]. Awareness is not attention, affordance or familiarity, nor consciousness. Awareness is given by a sense of presence in a dynamic context. It fluctuates, it is relational, and it is shown through user activities and their actions. Too little information awareness creates a lack of context understanding, whereas too much information awareness creates a mental workload. Fragmented information awareness is generated either through too little or through too much information awareness. When the user is no longer able to deal with and make sense of the information awareness, fragmented information awareness occurs.

Although a DLE is not a collaborative system per se, it is still regarded as an environment fostering cooperative settings that requires some coordination amongst the actors and their roles. It seems that when the individual needs to support awareness of the informational systems, some additional workload is added for the human. As a result of fragmented information awareness, users' actions change their course: new and different workflows are introduced to cope with it, and the workaround is performed. As a result, this creates overheads in terms of the consumed time resources, and additionally, increases the cognitive load of the user.

6.2 Information Awareness as Part of a System Ecology

This study showed an example of how the DLE used in HE institutions may create a complex, fragmented information awareness. This can be described as overwhelming: as many as 18 DLEs were used by the CIs, and many of those are used even by the students. SA regarding the use of DLE's amongst CIs is lacking or is characterized by disagreements, lack of rules, or information. SA amongst CIs and students is also flawed and depicted by a general one-to-many relationship. While, for a CI, somewhere between four to eight of the DLEs are visible, for a student, the DLEs from each CI are visible.

Switching context between these DLEs, as well as not all of these systems being universally designed, creates a fragmented information awareness amongst the CIs, and amongst the students. Moreover, some of these virtual environments are not complying with the UD law in Norway. The issue of fragmented awareness is similar to the studies talking about the ecology of artifacts [53]. However, it deals mainly with information ecology, which often becomes lost in-between systems, and with cognitive overload among users. Information ecology is a "system of people, practices, values, and technologies in a particular local environment. In information ecologies, the spotlight is not on technology, but on human activities that are served by technology." [54] Some examples of information ecologies are: a library, a hospital, a school, a university, a shop, or an institution. According to the authors, information ecology's focus is on the relationship between "tools and people and their

practices," "it is a complex *system* of parts and relationships" [54] (p. 50). The information ecology components develop and *coevolve* with each other in a dynamic fashion by complementing each other and forming a unity. While the elements in an information ecology are supposed to form some sort of dynamic symbiosis, we can say that the information ecology created by a fragmented information awareness is lacking information, making a place of "wholes of information".

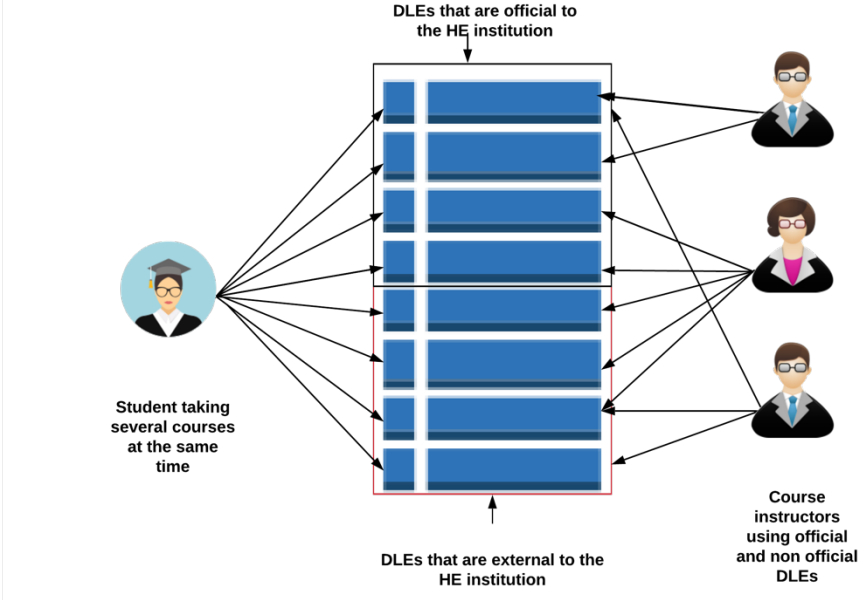

Fig. 1. An illustrative representation of students' and course instructors' relationships with DLEs

6.3 Context and Orderliness of Information Awareness

An ecological context should be presented as a context where the elements of the ecology intra-act with each other, with the aim of autopoiesis – supporting, re-producing, *befindlich* themselves virtually or physically [55]. As Dourish explains, the idea of context is dual. In essence, it has both a technical origin, representing the relationships between actions and systems and a social origin, representing aspects referring to the social setting [51]. Context as an interactional problem is presented in the literature as relational, between objects and activities, containing dynamic context features, and the context is particular to specific settings and emerges from activities [51]. Context is also linked to the idea of orderliness from within and from without [51]. Orderliness from without refers to social actions that derive from (external) rules

pre-set by an external organ [51]. Orderliness from within refers to the social actions that emerge from within the action itself [51].

Information Awareness Resulting from a Lack of Orderliness from Within. The specific use of DLEs and the expectations of the users on the same tool. Fragmented information awareness can result from a lack of *orderliness from within*. This was indicated by our findings when the students sought mediated feedback from CIs that was personalized and meaningful, and between students and CIs in terms of the visualization of feedback. Further, this phenomenon is also indicated by the challenge of language barriers in design, especially in the case of having several official languages. Another concern related to this phenomenon was suggested by the students feeling dis-empowered. The users indicated that the user should be in control and feel empowered.

Another example of fragmented information awareness from within was indicated by the tensions amongst CIs regarding the use of one system vs. several systems, in terms of the distribution of course materials amongst CIs, and between students and CIs; the fact that students have to adapt to different DLEs according to CIs' individual preferences; the structure of DLEs being different, and the expectations that the students (and CIs) will be able to use those, although sometimes the structure is not logical; the fact that email could potentially be a central junction when using different DLEs.

Gutwin et al. in [29] state that relaxed "What I See Is What You See" (WISIWYS) may "lead to a lack of awareness" [29]. Nevertheless, orderliness from within is strongly related to the look and feel of the digital façades and their affordances. For instance, we could observe in our study an incongruence in system image views amongst the actors.

Information Awareness Resulting from a Lack of Orderliness from Without. A user's fragmented information awareness from without is strongly related to their knowledge on the existing official vs. non-official DLEs and the local (institutional) agreements and procedures. Further, our findings from the interviews with CIs indicate that multiple DLEs and digital tools are used, but sometimes several of them are used for the same purpose. This contributes to fragmented information awareness amongst CIs and the students. Moreover, concerns about student privacy are not taken into account to date at an organizational level, when external tools are used. Finally, organizational memory suffers from a lack of clear processes and procedures in the documentation of final evaluations. Yet, this also adds to fragmented information awareness from without, in HE. Finally, the last layer of fragmented awareness from without refers to the knowledge of current laws, rules, and regulations regarding UD in HE.

6.4 Recommendations

Based on the empirical findings, and on our discussion around fragmented information awareness from within and from without, we have compressed the

learnings from this study into a few recommendations that may be valuable in other HE organizational entities, where several DLEs are used. Through our study, we have observed that: 1) many of the DLEs are not universally designed, and 2) fragmented information awareness occurs amongst the actors that use these DLEs. This also shows that there is a need for standards that also address cognitive elements. While developing those standards was outside of the scope of this study, we have developed a set of recommendations (Table 4) instead. The recommendations should support non-fragmented awareness, in the case of using multiple DLEs in HE. This set of recommendations is meant to support cognitive criteria for non-fragmented information awareness from within and from without. However, these criteria still eventually need to be transformed into measurable requirements.

Table 4. Set of recommendations

	Set of recommendations for the use of multiple DLE in HE
#	**Organizational recommendations for contributing to better awareness from without**
1	Systems should comply with existing laws and regulations at the national level.
2	No more than one DLE should be used for one purpose (e.g., publishing course material, submission, assessment, peer-review, supervision).
3	The use of multiple DLEs would benefit from agreements and rules set at a local level of the organization.
4	The DLEs used should comply with UD standards.
	Design recommendations for contributing to better awareness from within
5	The user should have the option of being notified through email when changes or updates are performed in any of the DLEs used.
6	Each DLE should follow a logical structure for the user.
7	A DLE dedicated to examination of students should include tools for performing drawing, visuals, schemes, and diagrams.
8	DLEs should support the distribution of course material in several formats and be accessible for those who cannot attend the class physically. This should not be in contradiction with personal data (e.g., voice recording) concerns of the individual who publishes it.
9	DLEs should support human-mediated feedback, that is: personal, fit the person or user receiving it, be careful (as opposed to involving careless feedback), clear (as opposed to vague), nuanced enough and represented through multimodalities (textual, audio, video, schematics), however, without being cluttered. Multimodal representation of it is recommended, such that language barriers that allow for unfortunate interpretation is dismissed or, at least, decreased at some level.
10	DLEs should support relevant, concrete, specific, multimodal, and adjustable system feedback. Each DLE's system feedback should be available in all the official languages. The system feedback should empower the user.
11	The user should be in control. The design of DLEs should: support the adjustments of the current system, rather than building new systems; have low barriers for accessing and using the system; be designed *for* people; give control to the user over the system; be universally designed, and invite human feedback.

7 Conclusion

This study focuses on DLEs, rather than on LMSs. This study goes beyond adopting the educational perspective, followed by classical studies on LMSs. DLEs are defined as a plethora of digital systems that may be used within a teaching/learning context, including LMSs, but also social media shared dashboards, communication tools, etc. used in such a context. The study is theoretically anchored within the HCI/CSCW concept of awareness, repurposing the concept for an educational setting. The novelty in this study consists of introducing a new form of awareness, namely *fragmented information awareness*. This form of awareness is described as a by-product, the overall theme of the study, generated by the use of multiple DLEs. The contribution of this paper lies in defining, describing, and addressing fragmented information awareness. The added value of the study relies upon addressing UD issues by suggesting a set of recommendations proposed for better information awareness, i.e., non-fragmented information awareness, that is presented from within and from without. However, the limitations of the study include that they only address UD from a background perspective, not rather than it being the main focus of the whole paper. Overall, the study subscribes to the fourth HCI wave, inheriting elements from both the third and fourth HCI waves.

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